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Drilling of Directional Wells in the Fields of Western Turkmenistan

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Abstract

The investigation of drilling directional wells in the fields of western Turkmenistan is relevant at the present time, as it can contribute to the optimisation of hydrocarbon production processes in the region, increasing the efficiency and sustainability of production. The purpose of this study is to analyse and evaluate aspects of drilling directional wells in the fields of western Turkmenistan to determine their potential for increasing hydrocarbon production and reducing operating costs. Among the methods used, the analytical method, the classification method, the functional method, the statistical method, and the synthesis method etc., should be noted. The study is an extensive examination of the experience of drilling directional wells and cluster drilling in western Turkmenistan's oil and gas fields, which considers modern technological advances. Within the framework of this study, potential directions for the development of technology for drilling directional wells were considered, and recommendations were formulated on the use of specialised equipment and high-quality materials for cluster drilling in the south-western part of Turkmenistan. The use of modern technical solutions that meet international standards has led to the successful completion of cluster drilling of directional wells at fields in this region. This study is a substantial starting point for the future development of the technology of cluster drilling of deep directional wells, especially considering high reservoir pressures, and it contributes to the technical renewal and organisational restructuring of the cluster drilling process based on scientific research. The study on drilling directional wells has practical value, enabling the optimisation of the production of oil and gas resources in difficult geological conditions and increasing the efficiency of production in this region.

Keywords

Horizontal termination; Landscape; Casing; Reservoir; Mining

Introduction

The study on the subject has a high practical importance and relevance. This region has substantial oil and gas reserves, and the effective use of modern drilling technologies allows optimising production and maximising the production of valuable energy

resources. Drilling directional wells is a technically complex process that requires highly qualified specialists and specialised equipment. The study on this subject allows increasing the level of professionalism of employees of the oil and gas industry, which contributes to the safety and efficiency of production. The development of recommendations and the use of advanced technologies in this area can substantially reduce production costs, reduce environmental impacts and contribute to the sustainable development of the oil and gas industry in western Turkmenistan. All these factors make the examination of this subject an extremely important step for the long-term development of the oil and gas industry in this region and on a global scale in general.

The problems of the study consist in several key aspects. Firstly, drilling directional wells in the fields of western Turkmenistan requires considering the specific features of the geological structure of the region, which can lead to difficulties in choosing the optimal angles of inclination and directions of wells. It is also necessary to consider reservoir pressures and other parameters to ensure safe and efficient drilling. Secondly, it is important to consider the issues of technical training and equipment necessary for drilling inclined wells and the development of cluster drilling. This may require the introduction of new technologies and materials and the training of qualified specialists. In addition, the issues include issues of environmental sustainability and minimising the harmful impact on the environment in the process of drilling and extraction of oil and gas resources. These aspects are becoming increasingly important in the modern oil and gas industry and require serious attention and research. Thus, the problems of the study are related to optimising the process of drilling directional wells, introducing modern technologies, ensuring safety and sustainability in extracting oil and gas resources in western Turkmenistan, and compliance with environmental standards.

As stated by Orazmetova (2023), the drilling of inclined wells is of particular importance in regions with limited access to large areas for installing drilling rigs, for example, in flat or oceanic fields. These technologies contribute to a substantial increase in the volume of extraction of valuable resources and optimisation of mining processes. Research in the field of directional well drilling actively contributes to the development of new materials and technologies capable of withstanding extreme conditions, such as high temperatures and pressures, which substantially increases the reliability and durability of drilling equipment. These innovations play a key role in improving the safety and efficiency of the drilling process (Deryaev, 2022; Drizhd, Mussin and Alexandrov, 2019). Khakimzyanov *et al*. (2021) noted that the use of directional wells is an effective method of reducing risks when drilling in difficult geological conditions, which becomes especially relevant for regions subject to seismic activity. Such wells can provide additional advantages in ensuring the stability and safety of the process of extracting oil and gas resources.

Orazmukhamedov (2023) points to the growing need for research aimed at optimising technologies for drilling inclined wells to improve their efficiency and reduce operating costs. These studies play an important role in improving the competitiveness of the oil and gas industry. As Abdyrahmanov (2019) notes, the knowledge gained as a result of research on drilling directional wells can be used not only in the oil and gas but also in the geothermal and exploration industries, which substantially expands the prospects for using this technology in various sectors of industry. This transfer of knowledge

contributes to the maximum use of experience and resources in various fields. According to Pulatov (2021), cooperation between researchers and industry in this area can contribute to faster innovation and improvement of the practical aspects of drilling inclined wells, which will ensure sustainable growth and development of the oil and gas industry. This interaction between science and industry is becoming a key factor in improving the efficiency and sustainability of the oil and gas sector.

The purpose of this study is to investigate the possibility of increasing hydrocarbon production and reducing operating costs by analysing and evaluating aspects of drilling directional wells in the fields of western Turkmenistan.

Materials and Methods

The methodology section for the study on drilling directional wells in the fields of Western Turkmenistan employs various research methods, each applied specifically to address different aspects of the investigation.

Analytical method

The analytical method was utilized to deeply understand the geological structure of the deposits in Western Turkmenistan. This analysis allowed for precise determination of optimal parameters for drilling directional wells, forming the basis for developing strategies aimed at optimizing hydrocarbon production stages and reducing operating costs. For foundational principles on the analytical method and its application in geological assessments, refer to J. Heinrich's (Katz, 1985) seminal work on analytical techniques in geology.

Statistical method

Statistical analysis was integral in examining data pertaining to the operation and productivity of directional wells. Relationships and correlations between drilling parameters and well productivity was identified, leading to the development of mathematical models for forecasting and optimizing hydrocarbon production. The statistical methods applied follow the guidelines set forth by Box and Draper (1987) in their comprehensive treatise on empirical model-building.

Functional method

The functional method was used to examine the operation specifics of drilling rigs and the technical parameters associated with directional drilling (Viola *et al.*, 2012). This method helped identify optimal equipment settings and technological solutions, increasing drilling productivity and reducing field operation time.

Structural-functional method

A structural-functional approach was crucial for understanding the interactions between different components of the drilling process (Barton, 2005). It allowed for the

identification of systemic weaknesses and bottlenecks, proposing targeted solutions for their optimization.

Deduction method

The deduction method was employed to derive general principles and patterns critical to the success of directional drilling operations in Turkmenistan (Schaeken *et al.*, 1999). Through logical reasoning based on accumulated data and prior experiences, key optimization strategies were formulated. Finally, the synthesis method facilitated the development of new technological solutions by integrating knowledge from various disciplines such as geology, engineering, and technical sciences, leading to more effective and sustainable hydrocarbon production solutions. For a foundational understanding of synthesis methodologies, refer to Kastner, Kaplan, and Sarrafzadeh (2004).

The study employed a multi-method approach, utilising the specific advantages of each method in addressing the complex issues associated with drilling directional wells. This was done with the aim of achieving a comprehensive evaluation and optimisation of drilling practices in Western Turkmenistan. The research timeline extended from the initial data collection phase through to the analysis and synthesis stages, spanning approximately two years. This reflected a rigorous and methodically planned approach to achieve the study's objectives.

Results

The drilling of directional wells in the fields of Western Turkmenistan is an important part of the oil and gas industry of this region (Figure 1). The results of the study and practical experience accumulated during the drilling of such wells are of great importance for optimising hydrocarbon production and ensuring sustainable economic activity in this sector (Deryaev, Amanov and Deryae, 2020; Iskandarov and Baghirov, 2022). This section will present the key results and conclusions obtained during the analysis of technical aspects and technological solutions used in drilling directional wells in this region. These results will help better understand modern methods and trends in drilling directional wells and identify prospects for further development of western Turkmenistan's oil and gas industry.

An inclined well is a complex engineering structure that is an integral part of the hydrocarbon production process. This type of well is characterised by the presence of a vertical or inclined shaft penetrating deep into the earth's crust and then changing its direction, heading in different directions to extract hydrocarbon resources from productive rocks. To ensure the efficiency and safety of operations, such wells are equipped with special casing pipes, cement shells, and filtration systems located in the oil or gas reservoir production field. These components perform important functions in maintaining the stability and productivity of the well, providing optimal conditions for extracting valuable hydrocarbon resources from the bowels of the earth (Lei *et al*., 2021; Dzhalalov, Kunayeva and Moldabayeva, 2021).

Figure 1: Western Turkmenistan (study area) map

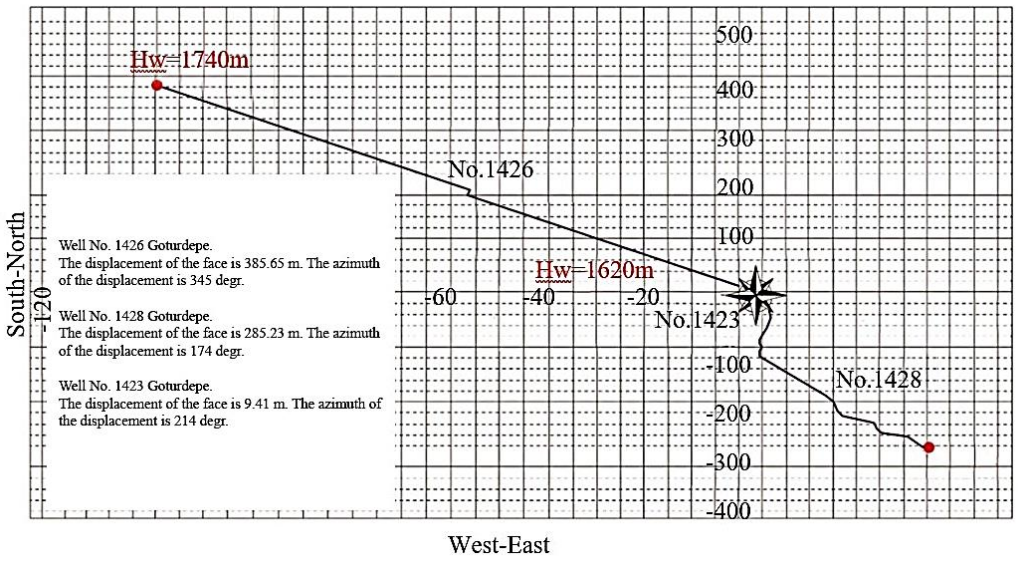

Figure 2: Horizontal projection (plan) of cluster wells No. 1428, 1426, 1423 of the Goturdepe field

The history of drilling directional wells in western Turkmenistan stretches for many decades. For example, at the Western Cheleken field, located on land and offshore overpasses, extensive drilling of directional wells with horizontal deviations of up to 400 m and even more was conducted in the 1950s-1960s of the last century. In addition, in the period from the 1970s to the 1980s of the last century, drilling of directional wells was widely practised at the Goturdepe and Barsagelmez fields. Even up to 40% of the total production volume at the Goturdepe field was conducted using directional wells for some years. Notably, the use of electric drilling in the Hoturdep played a substantial role, simplifying the process of orienting the diverter at the bottom of the well and making

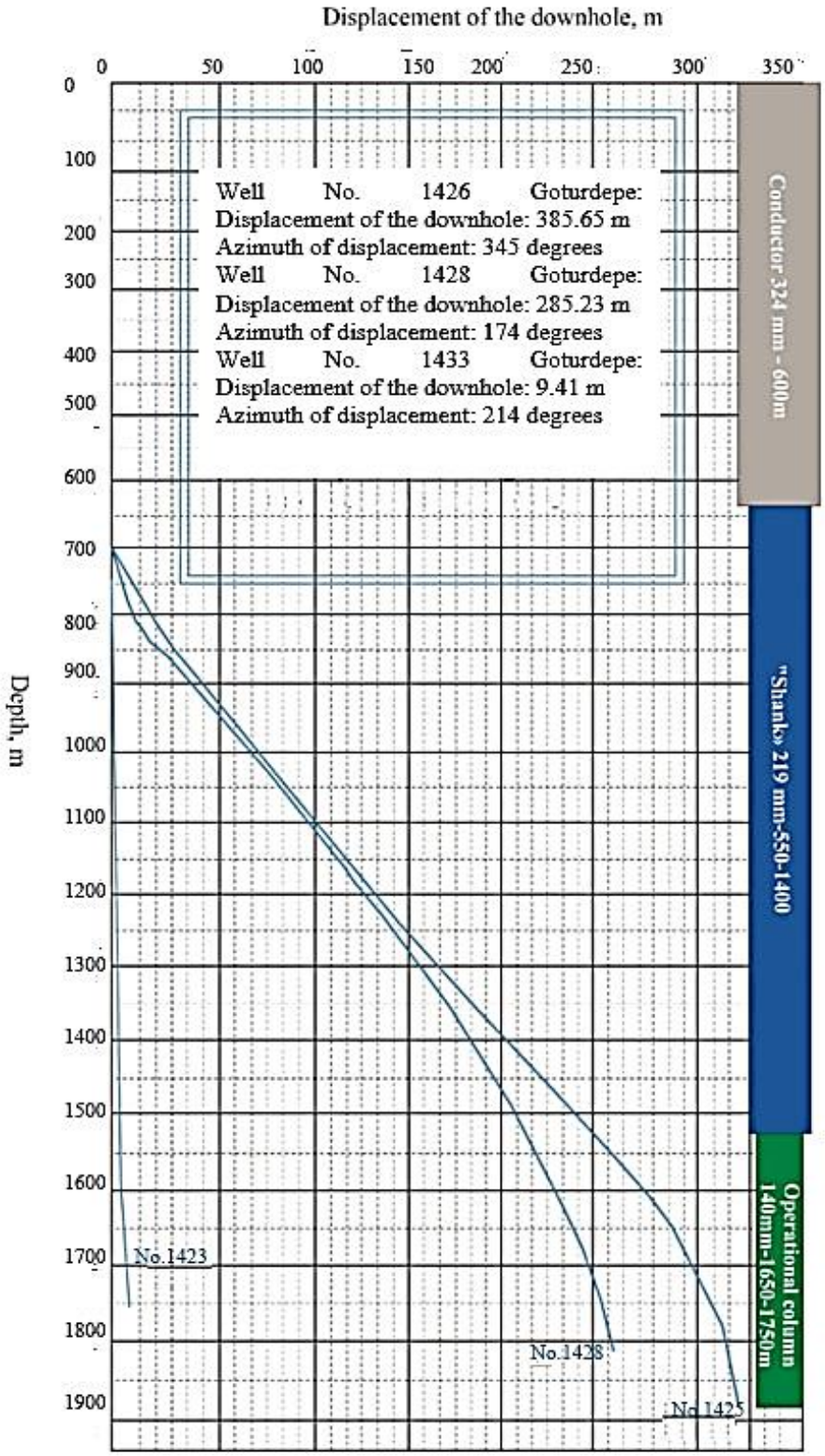

Figure 3: Vertical profile of cluster wells No. 1423, 1426, 1428 of Goturdepe "West"

the drilling of inclined wells more accessible and efficient. Since the beginning of the 2000s, modern methods of drilling directional wells have been actively used at the Dashoguz Group field to increase the volume of hydrocarbon production and optimise production processes. This choice is justified by the desire to use advanced equipment and technologies to achieve more accurate and efficient production results. Since the beginning of the 2010s, the active introduction of directional wells into the process of hydrocarbon production has been observed at the Karabogazgol field. This choice is justified by the desire to use advanced equipment and modern technologies that substantially increase the accuracy and efficiency of drilling (Al Saadi and Naidu, 2023).

The presence of extensive infrastructure, including an extensive network of communications, industrial equipment, and protected areas, such as power lines and pipelines, provided additional motives for drilling inclined wells. This situation opened up opportunities for efficient use of available free space and ensured coverage of almost all points of the grid of field development. In addition, the drilling of inclined wells has found its application in emergency situations, such as the separation of "secondary" wells, correction of the trajectory of wells with natural deviations exceeding the established limit values, and creation of hydrodynamic connections with emergency wells. These factors emphasised the importance and diversity of directional drilling applications in the context of fields with developed infrastructure (Hafezi, 2023; Petruk and Bilichenko, 2023).

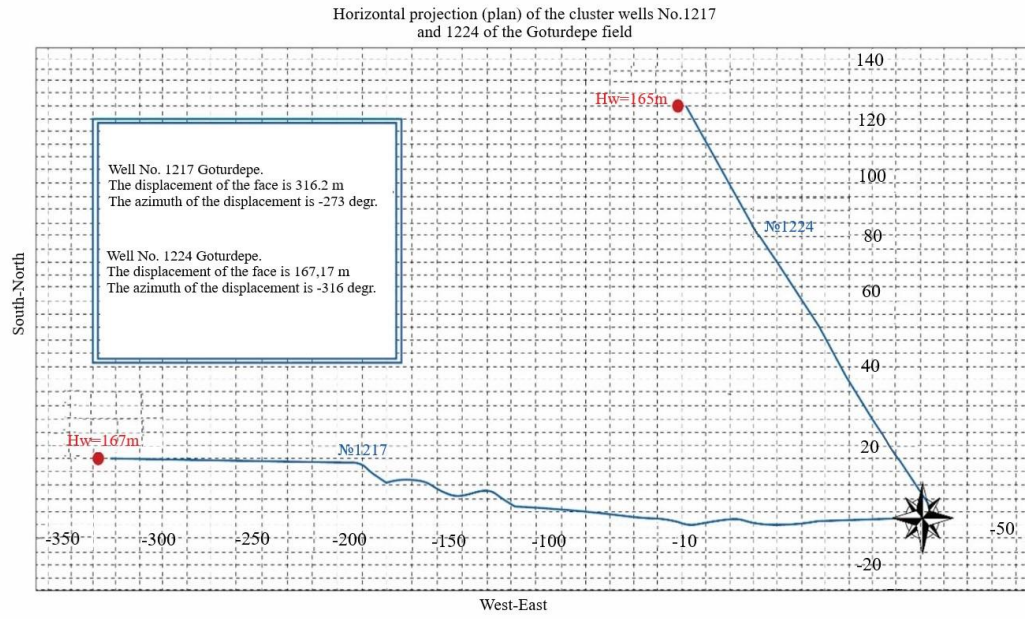

Figure 4: Horizontal projection (plan) of the bush of wells no. 1217 and 1224 of Goturdepe

With the development and improvement of directional drilling technology, it became possible to introduce cluster drilling of wells, in which several wells could be drilled simultaneously from one drilling site (Eren and Suicmez, 2020). Usually, a vertical well and 1-2 directional wells, and sometimes several inclined wells, were drilled at such a site. This method substantially reduced the time of well construction and resource costs for preparing new sites for the placement of drilling equipment since drilling a new well required only moving the drilling tower a short distance (6-10 m) and expanding the

drainage system. The number of wells in each bush drilling was determined only by the use of standard drilling rigs and not specialised for bush drilling. Horizontal and vertical projections of the trunks of some cluster wells that were drilled at the Goturdepe field in the 80s are shown in figures 2-5.

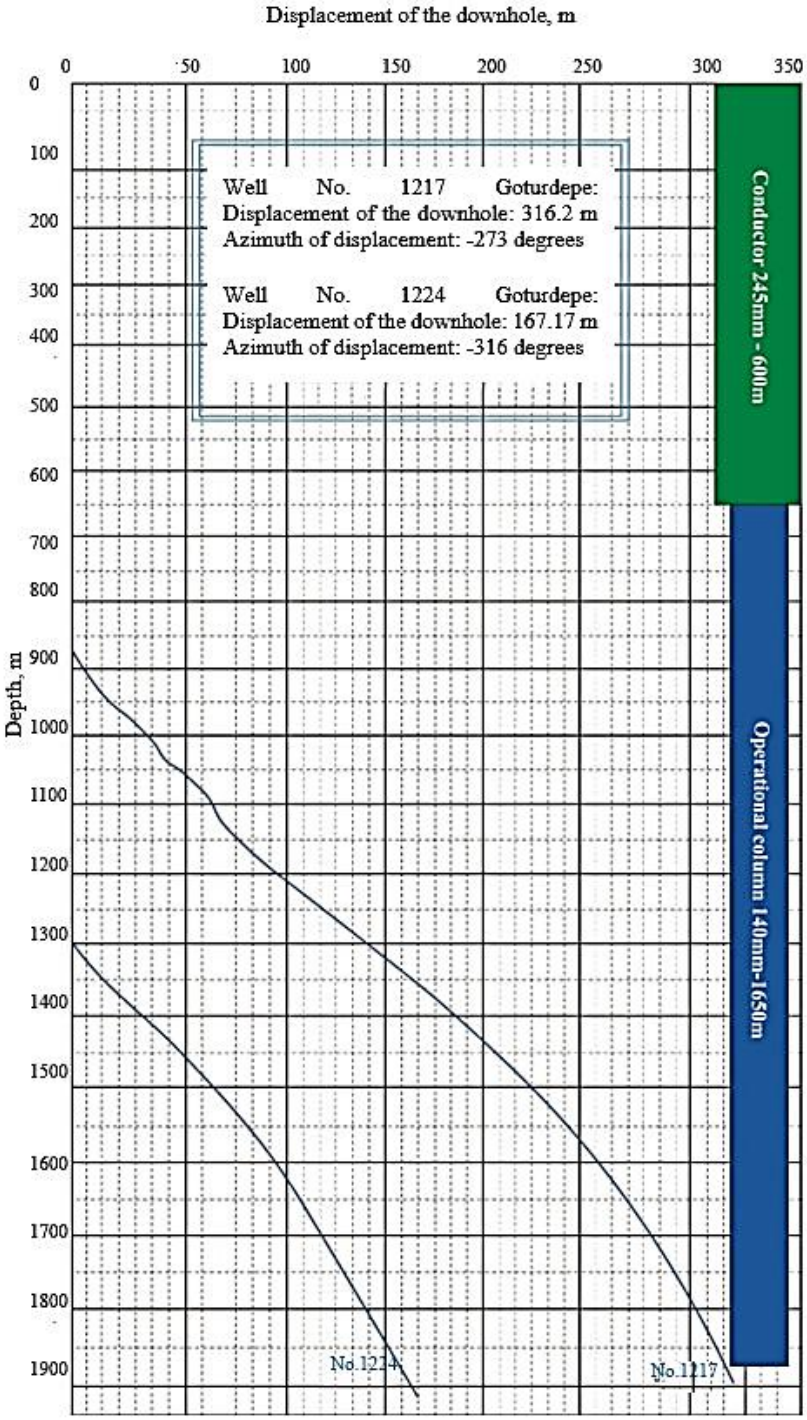

Figure 5: Vertical projection of cluster wells No. 1217 and 1224 of Goturdepe

Drilling of directional wells in western Turkmenistan in most cases, was conducted using electric drills. By that time, the drilling technology of electric drills was largely perfected, and a normal range of electric drills and auxiliary tools allowed for a wide range of changes in the layout of the bottom of the drilling tool for flexible control of the trajectory of the wellbore (Rossi *et al*., 2020). This allowed adjusting the configuration of the drilling tool to achieve precise control over the trajectory of the well. Notably, the main schemes used when drilling directional wells are shown in figure 6. These diagrams demonstrate various methods and technical approaches used to achieve the necessary orientation and direction of wells in a variety of mountain conditions of western Turkmenistan.

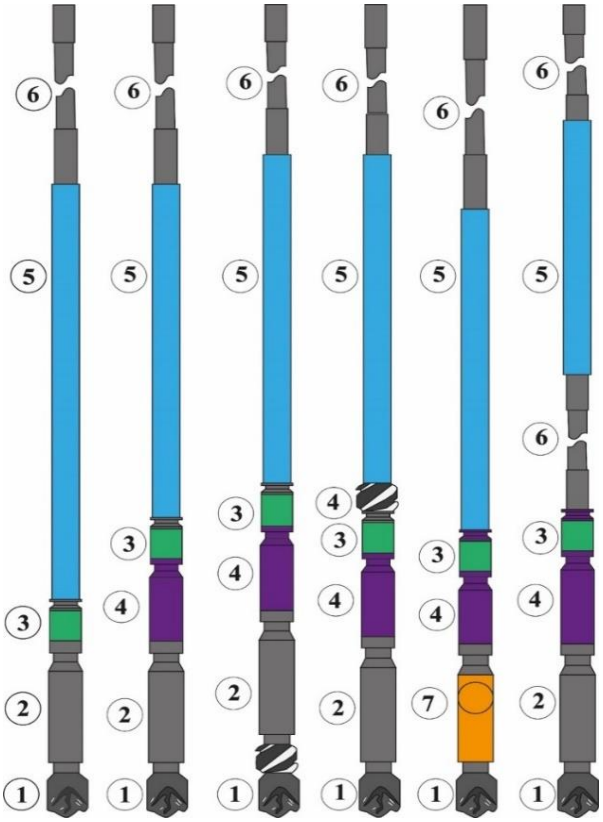

Figure 6: Layout diagram of the bottom of the drill string used for drilling directional and horizontal wells
Note: 1 – drill bit; 2 – electric drill with BM (bending mechanism 1-1.5-2O); 3 – deflector insulation monitoring device; 4 – traction power supply system; 5 – weighted drill pipes (WDP); 6 – drill pipes; 7 – electric drill with double BM; 8 – over-hammer calibrator; 9 – centraliser.

Currently, electric drilling is not a widespread drilling method in Turkmenistan (Schneising *et al*., 2020). Therewith, in world practice, there is an increase in the popularity of the method of drilling wells, including directional, using downhole hydraulic motors. The use of downhole telemetry systems (MWD and LWD) with a hydraulic communication channel in combination with downhole hydraulic motors

equipped with mechanisms of adjustable curvature allows drilling directional wells, similar to the method used in electric drilling (Fayemi *et al*., 2021). In south-western Turkmenistan, directional well No. 147 has been successfully drilled at the Northern Goturdepe field. Its drilling was conducted using the hydraulic downhole engine PowerPak A800M4553HR and the downhole navigation system "Telescope-825 NF".

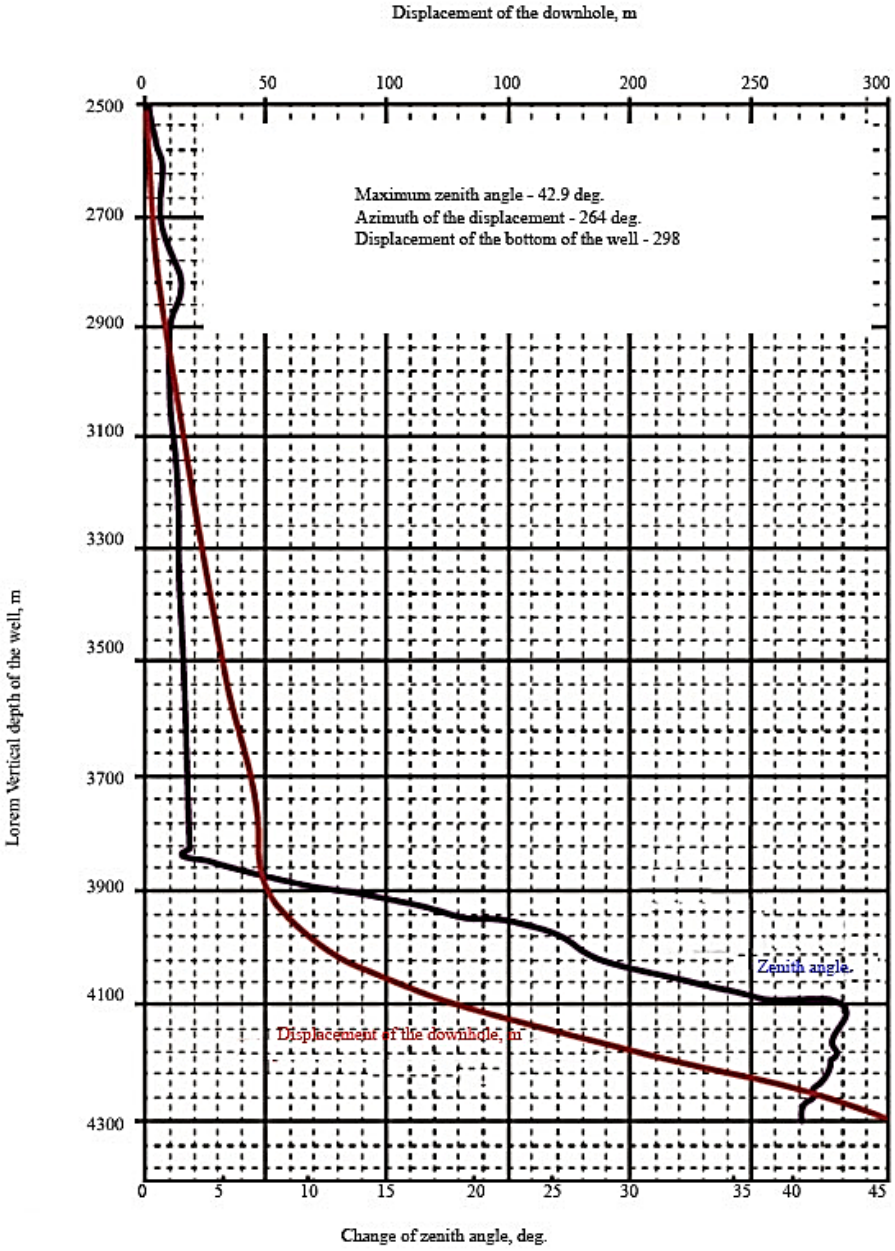

Figure 7: Zenith angle and displacement of the bore No. 147 of North Goturdepe

The figure 7 shows a vertical projection of the actual profile of the well, while Figure 8 shows the bottom drill string layout (BDSL) for well No. 147 at the North Goturdepe field. The well reached a maximum angle of inclination of more than 42 degrees and had

a downhole displacement of 297 m. Initially, the well was drilled vertically by rotary drilling to a depth of 3800 m. Then, it was gradually adjusted to tilt in increments of 1 degree for every 10 m through a hydraulic boring motor with adjustable curvature. At a depth of 4140 m vertically, a casing string with a diameter of 244.5 mm has been successfully installed.

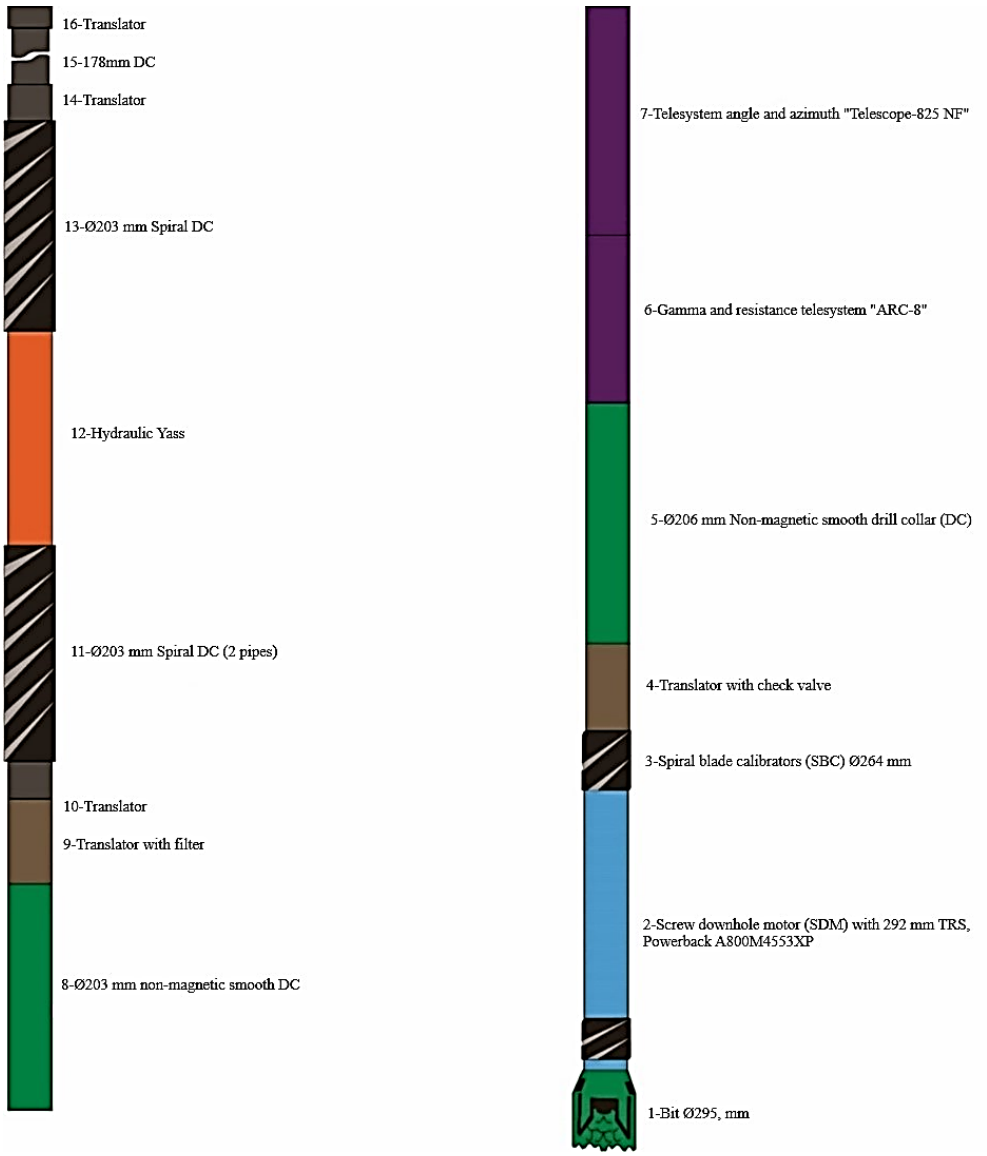
16-Translator
15-178mm DC
14-Translator
13-Ø203 mm Spiral DC
12-Hydraulic Yass
11-Ø203 mm Spiral DC (2 pipes)
10-Translator
9-Translator with filter
8-Ø203 mm non-magnetic smooth DC
7-Telesystem angle and azimuth "Telescope-825 NF"
6-Gamma and resistance telesystem "ARC-8"
5-Ø206 mm Non-magnetic smooth drill collar (DC)
4-Translator with check valve
3-Spiral blade calibrators (SBC) Ø264 mm
2-Screw downhole motor (SDM) with 292 mm TRS, Powerback A800M4553XP
1-Bit Ø295, mm

Figure 8: BDSL used for drilling directional well no. 147 North Goturdepe

Figure 8 shows the drill string, and Tables 1 and 2 show the technical parameters of this drill string, which were used when drilling a well. The exploration and development of the Northern Goturdepe field is actively conducted, covering areas both on land and in the waters of the Balkhan Bay of the Caspian Sea. Drilling of wells No. 37 and No. 147 was conducted using bulk islands-platforms (Ouadi, Mishani and Rasouli, 2023). Wells No. 200, 156, and 201 are currently drilled at the Northern Goturdepe field, also located

on bulk islands. Creating separate islands for each well requires substantial financial and labour costs. An effective solution to this problem is the drilling of several directional wells with branching boreholes, conducted from the same site.

Table 1: Technical characteristics of the BDSL layout used for drilling well No. 147 of Northern Goturdepe

Title	*Serial number*	*Outer and inner diameter, mm*	*Maximum diameter, mm*	*Connecting thread, type*
Bit Ø 295, mm	JD9768	209	295.3	-
		76		Z-152
Screw downhole motor (SDM) with 292 mm TRS, Powerpack A800M4553HR	7257	209	292	Z-152
		158.75		Z-152
Spiral blade calibrators (SBC) 264 mm	21065	207	264	Z-152
		76		Z-152
Translator with check valve	23021-1	218	218	Z-152
		76		Z-152
Ø 206 mm Non-magnetic smooth drill collar (DC)	DOT 22461	206	206	Z-152
		72		Z-152
Gamma and resistance telesystem “ARC-8”	2722	213	230	Z-152
		72		171 Z
Telesystem angle and azimuth “Telescope-825 NF”	V801	212	212	171 Z
		129		Z-152
Ø 205 mm non-magnetic smooth DC (2 pipes)	53199-1; 05SD21372-1	205	205	Z-152
		72		Z-152
Translator with filter	DFS 00515-6	212	212	Z-152
		72		Z-152
Translator	3898-9	214	214	Z-152
		72		Z-171
Ø 203 mm Spiral DC (2 pipes)	APT	203	203	Z-171
		72		Z-171
Hydraulic Yass	93626G	203	203	Z-171
		72		Z-171
Ø 203 mm Spiral DC	APT	203	203	Z-171
		72		Z-171
		200		Z-171
		72		Z-147
		180		Z-147
		58		Z-147
		173		Z-147
		98		Z-133

Table 2: Technical characteristics of the BDSL layout used for drilling well No. 147 of Northern Goturdepe

Title	*Serial number*	*Coupling/ Nipple (C/N)*	*Length, m*	*Length increase, m*	*Weight of the BDSL element, kg*
Bit Ø 295, mm	JD9768	C N	0.3	0.3	1093
SDM with 292 mm TRS, Powerpack A800M4553HR	7257	C C	8.9	9.2	2236
SBC Ø 264 mm	21065	N C	2.16	11.36	3241.2
Translator with check valve	23021-1	N C	1.23	12.59	3556.2
Ø 206 mm Non-magnetic smooth drill collar (DC)	DOT 22461	N C	8.56	21.15	5512.7
Gamma and resistance telesystem “ARC-8”	2722	N C	5.9	27.05	6878.6
Telesystem angle and azimuth “Telescope-825 NF”	V801	N C	8.3	35.35	8672
Ø 205 mm non-magnetic smooth DC (2 pipes)	53199-1; 05SD21372-1	N C	18.33	53.68	12815.3
Translator with filter	DFS 00515-6	N C	1.1	54.78	13083.7
Translator	3898-9	N C	0.44	55.22	13193.3
Ø 203 mm Spiral DC (2 pipes)	APT	N C	18.66	73.88	17317.8
Hydraulic Yass	93626G	N C	10.07	83.95	18716.4
Ø 203 mm Spiral DC	APT	N C N C N C N C	9.3	93.25	20772

The choice of parameters in the table is due to the need to provide detailed information about the components and characteristics of the drilling system, specifically the BDSL

element (bottom drill string layout) used during drilling. These parameters are important for the evaluation and control of drilling and help to optimise the process. The serial number uniquely identifies each element of the BDSL. This is important for accounting and monitoring the use of each part and determining their condition. The coupling/nipple indicates the type and characteristics of the connecting element of the BDSL, such as a coupling or nipple. Different connecting elements can be used for different drilling tasks and conditions. The length of the BDSL element plays an important role in determining the drilling depth and the distance to which the drilling string penetrates into the ground. This is important for understanding the characteristics of the well and planning work on its drilling and casing. An increase in length may indicate the ability of the BDSL element to expand or elongate. This may be important in cases where it is required to drill wells of a certain length or at different angles of inclination. The mass of the BDSL element is important for assessing its weight and determining what technical means are needed to lift it and install it on a drilling rig. These parameters provide important information about the design and characteristics of the BDSL elements, which helps to control and optimise the drilling process and ensure its safety.

The drilling of directional wells in the fields of western Turkmenistan is a high-tech and complex process that plays an important role in the production of oil and gas in this region. This drilling method was developed based on the need to overcome certain geological and technical challenges that are characteristic of the fields of western Turkmenistan. One of the main features of drilling inclined wells in this region is the use of various technical solutions, including electric drilling and hydraulic systems with hydraulic motors. These innovations allow overcoming the difficulties associated with the features of the geological structure of deposits, such as high angles of inclination and multidirectional rocks. The drilling of directional wells is a strategically important component of the development of oil and gas resources in western Turkmenistan. This method allows efficiently extracting hydrocarbons, optimising production, and ensuring the sustainable development of the oil and gas industry in this region.

Discussion

Drilling directional wells in the fields of western Turkmenistan is an important method that is successfully used for the extraction of hydrocarbon resources in this region. Inclined wells are a complex engineering structure that differs from conventional vertical wells. They start with a vertical or inclined drift, which then changes direction to extract oil or gas from productive rocks. Drilling directional wells has become an important part of hydrocarbon production in the region since the 50-60s of the last century. The Western Cheleken deposit was one of the first to use this technology. It was also actively used in the Goturdepe and Barsagelmez fields, where up to 40% of the total production was conducted using directional wells. One of the key advantages of this method has become cluster drilling, in which several wells can be drilled simultaneously from one drilling site. This substantially reduces the site preparation cost and the construction time of new wells. Modern technologies, such as electric drilling and downhole hydraulic motors, have supplemented and improved this method, making it more accurate and efficient. In addition, the drilling of directional wells has proved to be very useful in emergency situations. For example, it was used to separate “secondary” wells, correct the trajectory of wells, and create a hydrodynamic connection with emergency wells. With the

development of technology and new drilling methods, such as the use of downhole hydraulic motors and downhole telemetry systems, the drilling of directional wells has become even more accurate and efficient, which makes it an important element in the development of fields in western Turkmenistan.

As noted by Zalluhoglu *et al*. (2020), the downhole orientation fixation controller is an important technological component that revolutionised the process of drilling directional wells. Its ability to provide automatic control and correction of well orientation is of great importance for the oil and gas industry. Initially, drilling inclined wells required considerable effort and multiple corrections to achieve the desired trajectory. The downhole orientation fixation controller substantially simplifies this process, providing high accuracy and predictability in the direction of the well. This reduces the tortuosity of the path and substantially reduces drilling time, which is critical for efficient hydrocarbon production. It should be emphasised that downhole controllers provide increased safety at drilling sites, preventing possible accidents (Ismayilov, Iskenderov and Ismayilova, 2021; Mysak *et al.,* 2016). These innovations lead to more stable and efficient extraction of hydrocarbon resources, contributing to sustainability in the energy industry and ensuring reliable energy supplies for the global economy.

Ma *et al*. (2022) have shown that technologies for drilling methane from coal seams are critically important in the context of the coal industry and ensuring safe and efficient extraction of this important natural resource. They have undergone substantial development and improvement to meet modern safety and environmental sustainability requirements. The first stage in this process is the drilling of wells. Modern drilling technologies allow creating vertical and inclined wells with high precision and control. This reduces the risk of accidents and allows extracting methane from coal seams as efficiently as possible (Kondrat and Matiishyn, 2023; Samoilov and Redka, 2023). Notably, the use of directional wells can substantially increase production productivity and reduce environmental impacts since they allow methane to be extracted from a large area without the need to create many vertical wells. Injection of methane from coal seams also plays a key role in ensuring safety and minimising environmental impacts. Modern methods allow controlling and sealing wells, preventing methane leakage and protecting the environment (Dreshpak, 2023; Stavychnyi *et al.,* 2023). This is important for compliance with environmental regulations and sustainable methane production in the future. Thus, developing and applying modern technologies for drilling and pumping methane production from coal seams contributes to the efficiency, safety, and sustainability of this important energy sector.

Zhigarev *et al.* (2019) determined that the numerical examination of sludge transport by drilling mud in a horizontally directed well is an important aspect in drilling and well maintenance. Horizontal directional wells are widely used in the oil and gas industry, and effective drilling fluid management is critical for successful hydrocarbon production (Karpenko, 2023; Moldabayeva *et al.,* 2021). One of the key results of such numerical examinations is the optimisation of the parameters of the drilling process, such as the speed of circulation of drilling mud, its density, and viscosity. This minimises the likelihood of problems, such as the collapse of the walls of the well or clogging of drilling tools, which can slow down the drilling process and increase costs. It is worth adding that numerous studies allow analysing the impact of drilling mud on the

environment and developing measures to reduce potential environmental risks. This is important in the modern world, where environmental safety requirements are becoming more stringent (Korchevskiy and Kolesnyk, 2023). Thus, studies of sludge transport in horizontally directed wells not only contribute to improving drilling efficiency but also help to ensure the safety and sustainability of hydrocarbon production, meeting modern standards and regulations.

Deshmukh and Dewangan (2022) determined that well cleaning is the process of waste and rock recesses removal from the well during drilling. These parameters include a number of important aspects, such as the types of drilling fluids used, the circulation rate, the pressure at the bottom of the well, and the technical characteristics of the equipment. One of the key parameters is the choice of drilling mud, which must meet the characteristics of rocks and drilling conditions. A properly selected solution is able to prevent the collapse of the walls of the well and ensure the stability of drilling operations. In addition, the speed of drilling mud circulation is of great importance. It should be sufficient to effectively remove rock recesses and prevent the drilling tool from getting stuck. The pressure at the bottom of the well is also critical to prevent accidents such as ruptures or breakouts. The pressure must be controlled and maintained at safe levels in accordance with the characteristics of the rocks (Borisov *et al.*, 1987; Golyshev *et al.*, 2001). It is also necessary to consider the technical parameters of drilling equipment, such as pump performance and the capacity of equipment for processing rock recesses. It can be agreed that a review of the parameters of well cleaning during drilling emphasises the complexity and importance of this process. Proper management of these parameters contributes to safe and efficient operation in oil and gas fields, which is a key factor for the successful extraction of these valuable resources.

Referring to the definition by Mansouri *et al.* (2020), that optimisation of the separation coefficient along the trajectory of directional wells plays an important role in preventing the risk of collision between wells and ensuring the safety of drilling operations. This coefficient determines how close two wells can be to each other before there is a danger of intersection or interaction between them. Minimising the risk of collision is essential to prevent potential accidents and damage to the environment. One of the methods of optimising the separation coefficient is carefully planning the well trajectory. Engineers and geologists should consider the geological characteristics of the field to develop optimal paths for wells, minimising their mutual influence (Ali, Alkaabi and Lee, 2022; Astrelin *et al.*, 2019). This includes choosing the angle of inclination, direction and depth of the wells to ensure maximum separation between them. It is worth adding that it is important to use modern technologies and navigation systems, such as GPS and downhole telemetry systems, to accurately monitor the position and orientation of wells in real time. This allows operators to quickly respond to any deviations from the planned trajectory and prevent collisions. All these efforts are aimed at ensuring the safety and efficiency of drilling operations and minimising the risk of well collisions, which is a key aspect in the successful extraction of hydrocarbon resources (Sokolovskyi, Zharikov and Telenyk, 2024).

According to the results of recent studies by Hazbeh *et al*. (2021), comparing the accuracy and computational performance of machine learning algorithms in determining the penetration rate in directional wells is an important task in the modern oil and gas

industry. Effective control of the penetration rate is a key factor for achieving high drilling performance and reducing costs. One approach involves the use of machine learning algorithms that can analyse large amounts of data from sensors and drilling operations to determine the optimal penetration rate. These algorithms can consider various parameters, such as the geological characteristics of rocks and the properties of drilling tools, to predict the optimal drilling speed (Falko *et al.,* 2024; Korzhik, 1992). It can be agreed that comparing the accuracy of various machine learning algorithms in this area allows choosing the most effective methods for specific conditions and deposits. However, it is also important to consider computational performance, especially when working in real time. The integration of efficient machine learning algorithms into drilling systems can substantially increase the efficiency and control over the drilling process in directional wells, which ultimately leads to time and resource savings.

Conclusions

The drilling of directional wells in the fields of western Turkmenistan plays a key role in the development and production of hydrocarbon resources in this region. The established practice of drilling inclined wells in fields such as Western Cheleken, Goturdepe, and Barsagelmez confirms the successful implementation of this technology. The effective use of directional wells complements conventional drilling methods and substantially increases the overall productivity of deposits. The use of electric drilling and the subsequent improvement of this technology has made drilling inclined wells more efficient and affordable. The development of drilling methods using downhole hydraulic motors and downhole telemetry systems with a hydraulic communication channel has given a new impetus to the development of this technology, which allows drilling directional wells with accuracy and efficiency comparable to electric drilling. These innovations have become an integral part of the drilling of inclined wells in the region.

The accumulated experience in conducting directional drilling using electric drills and hydraulic downhole motors creates encouraging prospects for the future development of this technology in the fields of south-western Turkmenistan. When developing the Northern Goturdepe field, a rational solution is to use cluster drilling of wells from island sites and coastal zones, including one vertical and 1-2 directional wells with divergent trunks. The spread of the technology of cluster and directional drilling of wells to other fields of south-western Turkmenistan is a recommended solution that contributes to the optimisation of development processes and the efficient use of resources. It is important to emphasise that the drilling of inclined wells in western Turkmenistan has positively impacted the region's economy and energy security. This technology helps to optimise the production of hydrocarbons and reduce costs, making it a key element in the long-term strategy for developing deposits in this region. Additional research is needed to understand better the impact of various drilling parameters on the efficiency and accuracy of directional wells in the fields of western Turkmenistan.

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Author's Declarations and Essential Ethical Compliances

Author's Contributions (in accordance with ICMJE criteria for authorship)
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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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